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Resuscitation

Association between prehospital i-gel insertion and PCO_2 in patients with out-of-hospital cardiac arrest

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Objective: This study examined the initial partial pressure of carbon dioxide (PCO_2) as a possible indicator of prehospital ventilation and its association with prehospital i-gel in out-of-hospital cardiac arrest (OHCA) patients.

Methods: The demographics and arrest parameters, including i-gel insertion and initial arterial blood gas analysis, of OHCA patients who visited the emergency department were analyzed retrospectively. Linear regression analysis was performed to examine the association between i-gel insertion and the initial PCO_2.

Results: A total of 106 patients were investigated. Fifty-six patients had prehospital i-gel insertion and 50 patients did not have a prehospital advanced airway. The initial PCO_2 was higher in the i-gel group than the no advanced airway group (105.2 mmHg [77.5-134.9] vs. 87.5 mmHg [56.8-115.3], P=0.03). Prehospital i-gel insertion was associated with a higher initial PCO_2 level (β coefficient, 20.3; 95% confidence interval, 2.6-37.9; P=0.03).

Conclusion: Prehospital insertion of i-gel was associated with higher initial PCO_2 values in OHCA patients compared to no advanced airway.

Keywords: Airway management; Emergency medical services; Heart arrest; Cardiopulmonary resuscitation

INTRODUCTION

Out-of-hospital cardiac arrest (OHCA) results in low survival rates and a high possibility of poor neurologic outcome, which is a major public health burden.[1,2] As interventions performed by emergency medical services (EMS) can affect the outcome of OHCA patients, efforts to provide better prehospital care as well as airway management is of great importance.[3,4] The ease and high successful insertion rate of supraglottic airway (SGA) facilitates its prehospital use as an alternative to endotracheal intubation with minimal interruption of chest compression.[5] However, previous large multicenter studies have suggested inferior OHCA survival and neurologic outcomes with SGA compared to no advanced airway management.[6-8] The reasons responsible for such inferior outcomes of SGA are poorly understood. Several theories such as hyperventilation, increased intrathoracic pressure, chest compression interruptions, misplacement or dislodgement of the airway device, upper airway bleeding and edema, head and neck position leading to oropharyngeal air leaks and decreased carotid artery blood flow with SGA have been suggested.[9,10]

Current guidelines recommend continuous chest compressions with ventilations every 6 seconds with an advanced airway in place.[11] However, there is limited evidence about the ventilation adequacy with continuous chest compressions of each SGA device, especially for i-gel.[12] We hypothesized that hypoventilation subject to ventilation inadequacy may be a problem with prehospital i-gel insertion. Therefore, prehospital i-gel insertion

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Capsule Summary

What is already known in the previous study

The performance of i-gel during cardiopulmonary resuscitation has shown high insertion success rates with the ease of use, but failed to result in better outcomes in out-of-hospital cardiac arrest (OHCA) patients.

What is new in the current study

There is an association between prehospital i-gel insertion and the initial partial pressure of carbon dioxide in OHCA patients.

would be associated with higher hospital partial pressure of carbon dioxide (PCO_2) levels, possibly due to oropharyngeal leak and insufficient tidal volume.

The primary goal of this study is to investigate the initial in-hospital PCO_2 and analyze its association with prehospital i-gel insertion in OHCA patients.

METHODS

This study was approved by the Institutional Review Board of our institute (AJIRB-MED-MDB-16-517). Requirement of consent form was waived due to its retrospective nature.

1. Study design and setting

This was a retrospective single-center observational study of OHCA patients who visited our institute's emergency department (ED) from January 2014 to August 2016. Our hospital is a tertiary care regional academic hospital and the ED has an annual visit of approximately 87,000 patients. The Korean EMS system is a government based system with 16 provincial headquarters of the National Fire Department. EMS cannot declare death in the field unless there are obvious post mortem signs and cannot terminate cardiopulmonary resuscitation (CPR) unless return of spontaneous circulation (ROSC). Emergency medical technicians (EMTs) in Korea are classified into two levels. Level 1 EMTs can provide advanced prehospital airway management, and in some cases prehospital life support is assisted by video communication-based medical direction.[13] Due to its ease of use and placement,[6,14] i-gel has become the most commonly used prehospital SGA by EMS of our region.[13] OHCA patients received prehospital basic life support by our EMS including chest compression, ventilation and automated external defibrillation if the rhythm was shockable. Some patients were ventilated with an oropharyngeal airway and bag valve mask (BVM) in a 30:2 ratio, and some patients had prehospital i-gel insertion and continous chest compressions with ventilation every 6 seconds. Patients with prehospital i-gel insertion was allocated to the "prehospital i-gel group" and patients with oropharyngeal airway and BVM was allocated to the "no advanced airway group."

Upon arriving at our ED, advanced cardiac life support care according to the American Heart Association guidelines was provided with an initial arterial blood gas (ABG) analysis performed during cardiac arrest to investigate reversible causes.

Blood samples were collected from the radial or femoral artery using sodium-heparin-coated syringes. Blood gas analysis was performed using RAPIDPoint 400 (Siemens Healthcare, Munich, Germany). Reporting ranges were as follows: pH, 6.50-7.80; PCO_2, 9.97-150 mmHg; and partial pressure of oxygen (PO_2), 9.97-700 mmHg. For electrolytes, reporting ranges were as follows: sodium, 100-200 mmol/L; potassium, 0.5-15.0 mmol/L; chloride, 65-140 mmol/L; and ionized calcium, 0.2-5.0 mmol/L. Test results were available within 60 seconds.

All OHCA patients who visited our ED were included. Exclusion criteria were (1) age 18 or under, (2) no resuscitation attempted in the ED due to death upon arrival or do not resuscitate orders, (3) prehospital ROSC, (4) trauma, asphyxia or drowning as the cause of cardiac arrest as SGA cannot protect the airway from obstruction or aspiration, (5) patients who went under prior tracheostomy, unknown prehospital airway management, or patients who received an advanced airway device other than i-gel, (6) patients whose ABG were not performed or performed at 10 minutes or more after ED arrival, and (7) previously known underlying chronic obstructive pulmonary disease. After 10 minutes, the ED interventions likely would have affected the patient's physiology to make the PCO_2 a valid reflection of the prehospital care.

2. Data collection

Data from EMS reports, electronic medical records including a documented cardiac arrest data form and ABG results were retrospectively reviewed. Demographic data, prehospital arrest data including arrest location, witness of collapse, bystander CPR, prehospital automated external defibrillation, responder time (time from EMS call to scene arrival), transport time (time from EMS scene arrival to ED arrival) and advanced cardiac life support time (ED arrival to ROSC or termination of CPR) were collected. Hospital data including presumed cause of arrest, initial ABG time and results, cardiac arrest time, ROSC, and survival admission were also reviewed.

3. Statistical analysis

Continuous variables were reported as either median with interquartile range using Mann-Whitney U test for comparison or mean and standard deviation using two-tailed t test for comparison depending on normal distribution. Categorical variables were presented as frequencies and percentages, using chi-square test for comparison. After univariate linear regression for PCO_2, confounding variables other than age and sex with P-value of $\leq$0.2 were included for backward selection when modeling the multivariate regression analysis. Age, sex, bystander CPR, transport time, and prehospital i-gel use were variables included in the final multivariate linear regression model to investigate the association between prehospital i-gel insertion and initial PCO_2. Test for multicollinearity was done with variance inflation factors. Data were analyzed using Stata software, ver. 13 (Stata Corp LP, College Station, TX, USA).

RESULTS

1. Characteristics of study subjects

Of 679 OHCA patients who visited our ED, 573 were excluded based on the exclusion criteria. Therefore, a total of 106 patients were analyzed for this study, including 56 patients who had i-gel insertion and 50 patients who had BVM ventilation without prehospital advanced airway management (Fig. 1). Their baseline characteristics with initial ABG data and survival admission are summarized in Table 1. Initial PCO_2 was higher in the i-gel group compared to the no advanced airway group (105.2 mmHg [77.5-134.9] vs. 87.5 mmHg [56.8-115.3], P=0.03). Other demographic data and cardiac arrest variables, initial ABG results including pH, PO_2, bicarbonate, base excess, arterial O_2 saturation, and time to ABG were not significantly different between the two groups. A total of 14 patients (28.6%) survived at admission in the no advanced airway

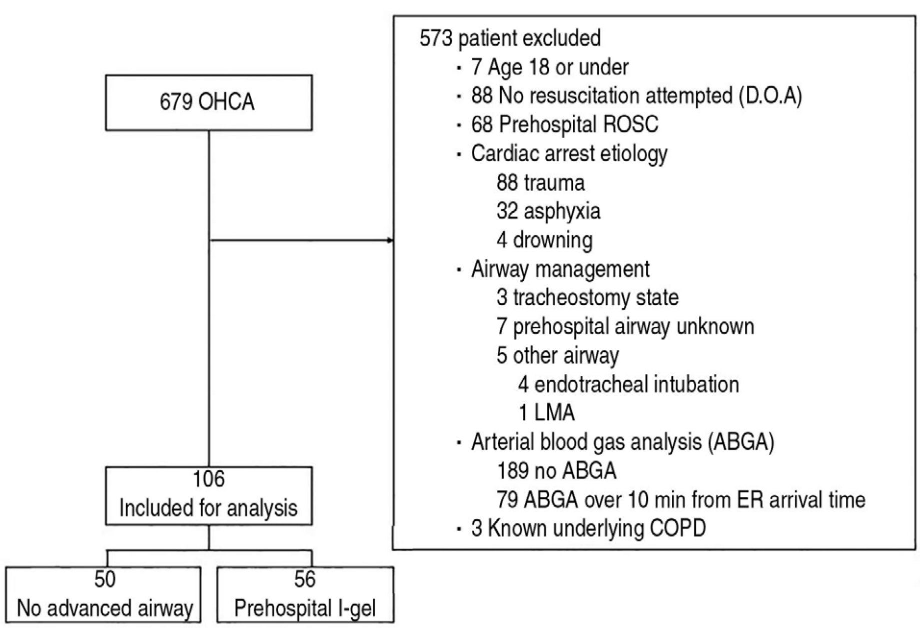

Fig. 1. Study flow. OHCA, out-of-hospital cardiac arrest; D.O.A, death on arrival; ROSC, return of spontaneous circulation; LMA, laryngeal mask airway; ER, emergency room; COPD, chronic obstructive pulmonary disease.

group while nine patients (16.1%) survived at admission in the i-gel group. The difference in survival rate between the two groups was not statistically significant (P=0.12).

2. Prehospital i–gel insertion and initial PCO_2

Multivariate linear regression analysis showed that prehospital i-gel insertion was associated with higher PCO_2, after adjusting for age, male sex, bystander CPR and transport time (β coefficient, 20.3; 95% confidence interval, 2.6-37.9; P=0.03). No multicollinearity was detected. Transport time was not statistically significant for PCO_2 level in the multivariate analysis (β coefficient, 0.5; 95% confidence interval, -0.2 to 1.1; P=0.15) (Table 2).

DISCUSSION

This was the first study to explore the initial PCO_2 of prehospital i-gel inserted OHCA patients. In our study,

Table 1. Baseline characteristics of study population

Variable	No advanced airway (n=50)	Prehospital i-gel (n=56)
Age, mean±SD (yr)	60.8±15.4	65.8±15.2
Male sex	30 (60.0)	43 (76.8)
Arrest location		
Home	20 (40.0)	30 (53.6)
Public location	9 (18.0)	4 (7.1)
Nursing	7 (14.0)	4 (7.1)
Other	13 (26.0)	12 (21.4)
Unknown	0	3 (5.4)
Witnessed arrest	34 (68.0)	33 (58.9)
Bystander CPR	32 (64.0)	37 (66.1)
Prehospital AED shock	10 (20.0)	10 (17.9)
Responder time (min)	10 (6 to 14)	10 (7 to 14.0)
Transport time (min)	25 (18 to 33.5)	37 (29 to 42)
Presumed cardiogenic	12 (24.0)	22 (39.3)
Arterial blood gas		
pH	6.85 (6.73 to 6.97)	6.78 (6.67 to 6.90)
PO_2 (mmHg)	43.2 (25.1 to 74.1)	38.6 (20.5 to 68.9)
PCO_2 (mmHg)	87.5 (56.8 to 115.3)	105.2 (77.5 to 134.9)
Bicarbonate (mmol/L)	14.7 (10.2 to 20.0)	16.1 (11.6 to 18.8)
Base excess (mmol/L)	-21.4 (-24.7 to -15.3)	-21.6 (-25.5 to -16.5)
SaO_2 (%)	39.1 (17.3 to 78.1)	32.9 (15.0 to 69.0)
Time to ABG, mean±SD (min)	5.5±2.3	5.5±2.5
ACLS time (min)	19.5 (11 to 28)	18 (12 to 27)
Survival admission	14 (28.0)	9 (16.1)

Values are presented as number (%) or median (interquartile range) unless otherwise indicated.
SD, standard deviation; CPR, cardiopulmonary resuscitation; AED, automated external defibrillator; PO_2, partial pressure of oxygen; PCO_2, partial pressure of carbon dioxide; SaO_2, arterial O_2 saturation; ABG, arterial blood gas; ACLS, advanced cardiac life support.

Table 2. Linear regression analysis for PCO_2

Variable	Multivariate B coefficient (95% CI)	P-value
Age	0.1 (-0.5 to 0.6)	0.83
Male sex	-13.0 (-31.1 to 5.1)	0.16
Bystander CPR	13.1 (-2.4 to 28.7)	0.10
Transport time	0.5 (-0.2 to 1.1)	0.15
Prehospital i-gel	20.3 (2.6 to 37.9)	0.03

F (p)=2.92 (0.02), R^2=0.15
PCO_2, partial pressure of carbon dioxide; CI, confidence interval; CPR, cardiopulmonary resuscitation.

prehospital i-gel inserted patients with continuous compression had higher initial PCO_2 compared to BVM ventilation.

Previous studies exploring the performance of i-gel during prehospital CPR have shown high insertion success rate with ease of use.[14,15] However, in nationwide studies of OHCA airway management strategies, survival was higher and neurologic outcome was better in patients who received no advanced airway compared to those receiving SGA.[6,7] As reasons to these results are unknown, we think our paper can generate a hypothesis. Air leak may be a common problem in prehospital i-gel ventilation during CPR.[14,16] In a study of chest compression performed on cadavers, the mean peak airway pressure arising from chest compression was 40.8 ± 16.4 cmH_2O,[17] while the mean airway leak pressure for i-gel ranges from 22-30 cmH_2O.[15,18] Therefore, if compression and ventilation is not perfectly synchronized during continuous compressions of CPR, massive air leak or i-gel dislodgement may occur, resulting in hypoventilation. It may be possible that prehospital i-gel as an advanced airway and continuous compression during cardiac arrest can cause this dyssynchrony and inadequate ventilation.

In the early phase of CPR, high quality chest compression and defibrillation might be of importance.[19] However, when CPR is prolonged towards the late circulatory phase, oxygenation and ventilation would be important for ROSC and outcomes. In one previous study, patients with PCO_2 <75 mmHg obtained during CPR was 3.3 times more likely to achieve ROSC in OHCA patients.[20] Hypercarbia was the main cause of acidosis in a study of blood gas analysis in on-going OHCA patients and hypocapnia was present in only 6% of the cases.[21] These studies suggest that adequate ventilation may need clinical attention in cardiac arrest patients, as well as avoidance of hyperventilation.[11] Although PCO_2 may not be an accurate surrogate of prehospital ventilation efficacy, higher initial PCO_2 in prehospital i-gel inserted patients imply that hypoventilation might be one factor resulting in inferior outcomes of prehospital SGA in OHCA patients.[6,7]

This study has several limitations. First, PCO_2 level is influenced by many causes, such as low perfusion during cardiac arrest and cardiac arrest duration, etiology of cardiac arrest, cardiac output or chest compression quality and ventilation rate etc. The long transport time in the i-gel group might have affected the increase in PCO_2. Also, as some cases might have had video communication-based life support in the field, this may have affected the results of our study. Advanced life support including drug therapy and prehospital field CPR may have caused longer transport times and can also affect the PCO_2 level.[13] Further studies with consideration of detailed prehospital treatment is needed for confirmation of our results. Despite these factors, we adjusted the transport time in the multivariate regression model and prehospital i-gel insertion was highly associated with PCO_2 level. Also, PCO_2 was higher in the prehospital i-gel group compared to the no advanced airway group when other blood gas analysis parameters (pH, PO_2, bicarbonate, base excess, and arterial O_2 saturation) were not significantly different. The level of respiratory compensation by the degree of metabolic acidosis was not considered and might have influenced the PCO_2 level. Moreover, although we tried to analyze the arterial blood, we might have obtained mixed samples or venous samples which is difficult to differentiate during cardiac arrest. Venous blood gas analysis has higher levels of PCO_2 compared to the arterial blood.[22] Second, the results of our study are based on a retrospective analysis in a single center, and are thus limited by possible biases that are intrinsic to such a design. Third, active prehospital CPR care by our regional EMS might have been provided for OHCA patients such as longer on-scene CPR, more drug therapy and advanced life support, more advanced airway management before being transported to our hospital. This can be critical to the study as this can cause interruption to cardiac compression or ventilation, as well as delay in CPR. We do not know how drug therapy such as epinephrine or amiodarone might have influenced the results. Further future studies with detailed data of prehospital CPR are required for confirmation of the findings of our study. Although this may have affected the findings of our study, the PCO_2 level was highly associated with i-gel insertion especially after correcting for transport time in our study. Fourth, airway management training and skills may differ from other EMS regions. Many unmeasured confounding factors such as regional characteristics of our EMS, individual EMS rescuer skill level, man power and differences in treatment during prehospital resuscitation may also exist. This may limit the generalization of this study. As i-gel insertion could have been influenced by video communication-based life support or the decision of the EMTs,[13] selection bias might have occurred with lack of information about this decision. Fifth, we used ABG results that were reported within 10 minutes of ED arrival. Selection bias might have occurred as patients with an ABG not obtained or obtained after 10 minutes of ED arrival were excluded. Also, the variation in sampling time may have affected the results of the study.

Despite many limitations, prehospital i-gel insertion was associated with higher initial PCO_2 level compared to no advanced airway management. Further prospective studies are needed with additional information for confirmation of these findings and investigating whether these findings might have been due to hypoventilation during OHCA.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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